JC20 Rec'd PCT/PTO 20 MAR 2002

FORM PTO-1390 OFFICE (REV. 11-2000)

U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
32860-000282/US

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)
10/088644

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE00/03143	September 11, 2000	September 20, 1999

TITLE OF INVENTION
METHOD ARRANGEMENT AND A PRODUCT OF A COMPUTER PROGRAM FOR SIMULATING A TECHNICAL SYSTEM

APPLICANT(S) FOR DO/EO/US
Claus HILLERMEIER; Wolfgang MAERKER; Thomas STURM

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau). WO 01/22178 A1
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is transmitted herewith.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4)
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 20. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98-1449 and International Search Report (PCT/ISA/210) in German with Six (6) references and a German Translation Aid
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☒ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
    1) THREE (3) sheets of Formal Drawings

10/088644 032002

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U.S. APPLICATION NO (if known, see 37 CFR 1 5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
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21. ☒ The following fees are submitted

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1,040.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO. **$710.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4). **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 0	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	CALCULATIONS	PTO USE ONLY
Total Claims	43 - 20 =	23	X $18.00	$ 414.00	
Independent Claims	3 - 3 =	0	X $84.00	$ 0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		None	+ $280.00	$ 0	
TOTAL OF ABOVE CALCULATIONS =				$ 1,304.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$ 0	
SUBTOTAL =				$ 1,304.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐20 ☐30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$ 0	
TOTAL NATIONAL FEE =				$ 1,304.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 40.00	
TOTAL FEES ENCLOSED =				$ 1,344.00	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of $ 1,344.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account. No. 08-0750 in the amount of $ to cover the above fees. A triplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 08-0750.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

Send all correspondence to.

Harness, Dickey & Pierce, P.L.C – Customer No. 30596
Post Office Box 8910
Reston, Virginia 20195

Date: MARCH 20, 2002

By [signature]
Donald J. Daley, #34,313

/kna

PATENT
32860-000282/US

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicants: Claus HILLERMEIER; Wolfgang MAERKER; Thomas STURM

Int'l App. No.: PCT/DE00/03143

Application No.: **NEW**

Filed: March 20, 2002

For: METHOD ARRANGEMENT AND A PRODUCT OF A COMPUTER PROGRAM FOR SIMULATING A TECHNICAL SYSTEM

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, DC 20231

March 20, 2002

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

IN THE ABSTRACT

Please replace the Abstract with the attached revised Abstract.

IN THE CLAIMS

Please amend the claims as follows:

1. (Amended) A method for simulation of a technical system, in which a function depends on parameters and on setting constants, comprising:

determining a result in the form of an influence of the parameters on the technical system, as a function of a set of parameters and on the basis of a request to an external source;

temporarily storing the result; and

simulating the technical system on the basis of the result and of the setting constants.

2. (Amended) The method as claimed in claim 1, further comprising:

designing the technical system on the basis of the simulation.

3. (Amended) The method as claimed in claim 2, wherein the design process includes at least one of an adaptation of, a change to, and a redesign of the technical system.

4. (Amended) The method as claimed claim 1, further comprising:

redetermining the influence of the parameters on the technical system by accessing the temporarily stored result.

5. (Amended) The method as claimed in claim 1, wherein the influence of each of a plurality of sets of parameters on the technical system is determined by checking the external source, and wherein the result of this check is temporarily stored.

6. (Amended) The method as claimed in claim 5, wherein an additional influence is determined on the basis of the temporarily stored results.

7. (Amended) The method as claimed in claim 6, wherein the additional influence is determined by at least one of interpolation and extrapolation.

8. (Amended) The method as claimed in claim 6, wherein the additional influence is determined from the results using an neural network.

9. (Amended) The method as claimed in claim 1, wherein the external source is at least one of a simulator and an experiment.

10. (Amended) The method as claimed in claim 1, wherein the simulation is carried out using a plurality of results, without the external source.

11. (Amended) The method as claimed in claim 1, further comprising:

determining, from the simulation of the technical system, the sensitivity of sets of parameters to changes in the setting constants.

12. (Amended) An arrangement for simulation of a technical system, comprising:

a processor unit wherein, a function depends on parameters and setting constant, wherein the processor unit is adapted to determine a result in the form of an influence of the parameters on the technical system as a function of a set of parameters and on the basis of a request to an external source; and

a memory, adapted to temporarily store the result, wherein

the processor is adapted to simulate the technical system on the basis of the result and of the setting constants.

13. (Amended) A computer program product, adapted to cause a processor unit to simulate a technical system, wherein a function depends on parameters and setting constants, comprising:

a first program segment, adapted to cause the processor unit to determine a result, in the form of an influence of the parameters on the technical system, as a function of a set of parameters and on the basis of a request to an external source;

a second program segment, adapted to cause the processor unit to cause the result to be temporarily stored; and

a third program segment, adapted to cause the processor unit to simulate the technical system on the basis of the result and of the setting constants.

Please add the following new claims:

-- 14. The method as claimed claim 2, further comprising:

redetermining the influence of the parameters on the technical system by accessing the temporarily stored result.

15. The method as claimed claim 3, further comprising:

redetermining the influence of the parameters on the technical system by accessing the temporarily stored result.

16. The method as claimed in claim 2, wherein the influence of each of a plurality of sets of parameters on the technical system is determined by checking the external source, and wherein the result of this check is temporarily stored.

17. The method as claimed in claim 16, wherein an additional influence is determined on the basis of the temporarily stored results.

18. The method as claimed in claim 17, wherein the additional influence is determined by at least one of interpolation and extrapolation.

19. The method as claimed in claim 17, wherein the additional influence is determined from the results using an neural network.

20. The method as claimed in claim 2, wherein the external source is at least one of a simulator and an experiment.

21. The method as claimed in claim 2, wherein the simulation is carried out using a plurality of results, without the external source.

22. The method as claimed in claim 2, further comprising:

determining, from the simulation of the technical system, the sensitivity of sets of parameters to changes in the setting constants.

23. The arrangement of claim 12, wherein the processor unit is further adapted to design the technical system on the basis of the simulation.

24. The arrangement of claim 23, wherein the design process includes at least one of an adaptation of, a change to, and a redesign of the technical system.

25. The arrangement of claim 12, wherein the processor unit is further adapted to redetermining the influence of the parameters on the technical system by accessing the temporarily stored result.

26. The arrangement of claim 12, wherein the influence of each of a plurality of sets of parameters on the technical system is determined by checking the external source, and wherein the result of this check is temporarily stored.

27. The arrangement of claim 26, wherein an additional influence is determined on the basis of the temporarily stored results.

28. The arrangement of claim 27, wherein the additional influence is determined by at least one of interpolation and extrapolation.

29. The arrangement of claim 27, wherein the additional influence is determined from the results using an neural network.

30. The arrangement of claim 12, wherein the external source is at least one of a simulator and an experiment.

31. The arrangement of claim 12, wherein the simulation is carried out using a plurality of results, without the external source.

32. The arrangement of claim 12, wherein the processor unit is further adapted to determine, from the simulation of the technical system, the sensitivity of sets of parameters to changes in the setting constants.

33. The computer program product of claim 13, including a computer readable medium.

34. The computer program product of claim 13, further comprising a fourth program segment, adapted to cause the processor unit to design the technical system on the basis of the simulation.

35. The computer program product of claim 13, wherein the design process includes at least one of an adaptation of, a change to, and a redesign of the technical system.

36. The computer program product of claim 13, further comprising a fourth program segment, adapted to cause the processor unit to redetermine the influence of the parameters on the technical system by accessing the temporarily stored result.

37. The computer program product of claim 13, wherein the influence of each of a plurality of sets of parameters on the technical system is determined by checking the external source, and wherein the result of this check is temporarily stored.

38. The computer program product of claim 37, wherein an additional influence is determined on the basis of the temporarily stored results.

39. The computer program product of claim 38, wherein the additional influence is determined by at least one of interpolation and extrapolation.

40. The computer program product of claim 38, wherein the additional influence is determined from the results using an neural network.

41. The computer program product of claim 13, wherein the external source is at least one of a simulator and an experiment.

42. The computer program product of claim 13, wherein the simulation is carried out using a plurality of results, without the external source.

43. The computer program product of claim 13, further comprising a fourth program segment, adapted to cause the processor unit to determine the influence of the parameters on the technical system by accessing the temporarily stored result determining, from the simulation of the technical system, the sensitivity of sets of parameters to changes in the setting constants. --

REMARKS

Claims 1-43 are now present in this application, with new claims 14-43 being added by the present Preliminary Amendment. It should be noted that the amendments to original claims 1-13 of the present application are non-narrowing amendments, made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations. For example, amendments have been made to broaden the claims; remove reference numerals in the claims; remove the European phrase "characterized in that"; remove multiple dependencies in the claims; and to place claims in a more recognizable U.S. form, including the use of the transitional phrase "comprising" as well as the phrase "wherein". Other such non-narrowing amendments include placing apparatus-type claims (setting elements forth in separate paragraphs) and method-type claims (beginning elements, set forth in separate paragraphs with "-ing" verbs) and computer product-type claims (program segments set forth in separate paragraphs) in a more recognizable U.S. form. Again, all amendments are non-narrowing and have been made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations.

SUBSTITUTE SPECIFICATION

In accordance with 37 C.F.R. §1.125, a substitute specification has been included in lieu of substitute paragraphs in connection with the present Preliminary Amendment. The substitute specification is submitted in clean form, attached hereto, and is accompanied by a marked-up version showing the changes made to the original specification. The changes have been made in an effort to place the specification in better form for U.S. practice. No new matter has been added by these changes to the specification. Further, the substitute specification includes paragraph numbers to facilitate amendment practice as requested by the U.S. Patent and Trademark Office.

CONCLUSION

Accordingly, in view of the above amendments and remarks, an early indication of the allowability of each of claims 1-43 in connection with the present application is earnestly solicited.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Donald J. Daley at the telephone number of the undersigned below.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 08-0750 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

HARNESS, DICKEY & PIERCE, P.L.C

By: ______________________
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DJD:kna

ABSTRACT OF THE DISCLOSURE

A method is specified for simulation of a technical system, in which a required function depends on parameters and predetermined setting constants. A result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source. The result is temporarily stored. The technical system is simulated on the basis of the result and of the setting constants.

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MARKED-UP SPEC

~~Description~~

Product of A

PCT/DE00/03143) **Method, Arrangement And Computer Program ~~product~~ For ~~simulation of a~~ Simulating A Technical System**

PCT/DE00/03143

FIELD OF THE INVENTION

The invention generally relates to a method, an arrangement and a computer program product for simulation of a technical system.

BACKGROUND OF THE INVENTION

Various approaches are known ~~[1]~~ (see [1] for example), for optimization of a technical system, in particular for global optimization. If the system to be optimized is a complex structure which is difficult to describe analytically, or cannot be described at all, then a simulation is frequently carried out for a specific configuration of the technical system. In a simulation such as this, a configuration or a reaction of the technical system is calculated as a function of a large number of setting parameters. Since there are a large number of setting parameters and an immense number of computation operations involved in determining the configuration of the technical system for specific sets of setting parameters, this involves an enormous amount of computation effort. If all the possible setting parameters of interest are combined to form a so-called parameter vector x, then this results in a simulation response y of dimension m for each case of this parameter vector in a dimension n.

For (global) optimization, as good a configuration as possible, or as good a setting as possible, of the technical system is determined for a required function *f*. However, in addition to the setting parameters which are provided for the technical system and which can be varied during an optimization calculation, it is now also possible for so-called setting constants to occur which cannot be varied in a corresponding manner during the optimization calculation, and which are thus

not variables (= can be varied) for optimization purposes. Nevertheless, these setting constants are of major importance since they influence the required function. One example of such setting constants is cost constants which, in some circumstances, vary severely, to a greater or lesser extent, over the course of time. If the cost constants change beyond a certain amount, and assuming that the required function includes costs, this may result in a change in the result during the course of the optimization process. It is now a major disadvantage to have to carry out the simulation process once again, as described above, if the cost constants change, thus resulting in the enormous computation effort being incurred once again.

SUMMARY OF THE INVENTION

An ~~The~~ object of an embodiment of the invention is to allow a technical system to be simulated without having to carry out unnecessary time-consuming simulation steps more than once.

This object ~~is~~ can be achieved, for example, by a method for simulation of a technical system ~~according to the features of the independent patent claims. Developments~~ are ~~described in the dependent claims~~.

In order to achieve ~~the~~ such an object, an embodiment of the invention specifies a method for simulation of a technical system, in which a required function depends on parameters and predetermined setting constants. A result in the form of an influence of the parameters on the technical system ~~is~~ can be determined as a function of a predetermined set of parameters and on the basis of a request to an external source. The result ~~is~~ can be temporarily stored. The technical system ~~is~~ can be simulated on the basis of the result and the setting constants.

In this case, it ~~is~~ can be particularly advantageous that the process of determining the value of the required function ~~is~~ can be split into determination of the influence of the parameters on the technical system and determination of the influence of the setting constants on the technical system. It ~~is~~ can thus be possible to optimize the time-consuming and computation-intensive check with the external source such that, in particular, once results have been determined, they can be reused for further simulation purposes.

One development ~~comprises~~ can include the technical system being designed on the basis of the simulation. In particular, in this case, the technical system can be

- redesigned,
- adapted,
- configured, or
- controlled.

Redesign preferably ~~comprises~~ includes recreation of the technical system, for example of a process technology system, of a circuit or of a software system.

Adaptation co~~mprises~~ can include a change to an existing system, for example in order to improve its operation. Configuration may c~~omprise~~ include defining not only the sizes but also settings of components, for example of physical dimensions of parts of a technical system. Finally, control allows the variable system parameters to be set efficiently so that, in particular, it is possible to ensure that it operates as efficiently as possible.

One refinement ~~is~~ can be for the influence of the parameters of the technical system to be redetermined by accessing the temporarily stored result. This temporary storage step saves a considerable amount of computation effort and time.

Another development ~~is~~ can be to determine the influence of each of a large number of sets of parameters on the technical system by checking with the external source, and then temporarily store the result of this check. In this case, it is advantageous that a number of checks result in a number of results, whose temporary storage defines a (multidimensional) plane in a (multidimensional) space. This plane is defined with greater accuracy, the greater the number of checks that are carried out with the external source (for example the simulator). If the plane has been defined sufficiently accurately, that is to say it has a sufficient number of support points, then further (multidimensional) points on the same plane can be determined by interpolation or extrapolation, even without any checks. Such an interpolation/extrapolation method is generally considerably less time-consuming and computation-intensive than the determination process by means of a simulator.

In one development, a number of results ~~are~~ can also be initially determined and ~~are~~ can be temporarily stored. Additional points can then be determined without any further check with the external source by means of a neural network, with the stored results being provided as a training set to the neural network. A neural network such as this may, in particular, be in the form of a multilayer perceptron ~~(see [2]).~~ (see [2] for example).

The check with the external source may, in particular, be carried out so that the external source itself represents a complex simulation program, on the basis

of which, and depending on the set of parameters, a result ~~is~~ can be calculated for that configuration or more detailed description of the technical system. One alternative to this is to carry out the check with an external source ~~by means of~~ via an experiment.

In another refinement, the simulation of the large number of results ~~is~~ can be carried out without any further check with the external source. In particular, the temporarily stored multidimensional description of the results which have already been determined from checks that have been carried out can be used to carry out a further simulation without any need for the complex mechanism for determining the results in the form of the external source.

In an additional refinement, the method for simulation of a technical system as described above ~~is~~ can be used in a sensitivity analysis. In this case, the sensitivity of the optima (the

variable parameters) to changes to the predetermined setting constants is determined.

Furthermore, in order to achieve ~~the~~ an object, an arrangement for simulation of a technical system ~~is~~ can be specified, in which a processor unit is provided which ~~is~~ can be set up such that:

1. a required function depends on parameters and predetermined setting constants;
2. a result in the form of an influence of the parameters on the technical system can be determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
3. the result can be temporarily stored; and
4. the technical system can be simulated on the basis of the result and of the setting constants.

Furthermore, a computer program product (article of manufacture) ~~is~~ can be specified in order to achieve ~~the~~ an object, which is intended for simulation of a technical system and, when run on a processor unit, ~~comprises~~ includes the following steps:

1. a required function depends on parameters and predetermined setting constants;
2. a result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
3. the result is temporarily stored; and
4. the technical system is simulated on the basis of the result and of the setting constants.

The arrangement and the computer program product are particularly suitable for carrying out the method according to an embodiment of the invention, ~~or~~ and/or one or more of its developments explained above.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the invention will be described and explained in the following text with reference to the drawings, in which:

Figure 1 shows a method for simulation of a technical system;

Figure 2 shows a method for simulation of a technical system with a temporary store;

Figure 3 shows a method for simulation of a technical system with automatic grid sampling;

Figure 4 shows a method for simulation using a simulation database; and

Figure 5 shows a processor unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a method for simulation of a technical system, in particular of a power station. Required function evaluation 102 depends on the results from external sources, in this case an external simulator 106 which is linked via a "power station link" interface 105. Furthermore, the required function evaluation 102 depends on setting constants, in this case cost constants 103. This thus results in the following relationship:

$$f_{\alpha,\beta,\ldots}(\mathbf{x}) = F_{\alpha,\beta,\ldots} \circ \underbrace{\phi(\mathbf{x})}_{\mathbf{y}\in\mathbb{R}^{n+m}}, \mathbf{x} \in \mathbb{R}^n. \qquad (1)$$

Here, f denotes the required function, which depends on the cost constants α, β, ... and is split into a component F, which includes the cost constants, into a component ϕ, which comprises the parameters $x = (x_1, x_2, \ldots, x_n)^T$, which can be influenced during the course of the optimization process. The character "O" in the above formula (1) denotes that two functions are carried out successively.

A (global) optimization of the required function f, which is provided by the required function evaluation 102, is carried out in an optimization process 101. The result of the optimization process 101 is used, in

particular, for a new entry into the required function, so that another optimization process 101 can be carried out taking into account the cost constants 103. In particular, this method is reiterated until a predetermined quality has been achieved, or the further improvement between the most recent iterations is not significant. Results from the required function evaluation 102 are preferably stored in a record file 104.

Figure 2 is an expansion of Figure 1, in which a simulation interface 201 with a simulation database 202 is inserted. The simulation interface 201

means that the result of each check with an external source, in this case via the power station link 105 and the simulator 106, is temporarily stored in the simulation database. If the same check with the simulator 106 were to occur at a later time, then there is no need for this to start another time-consuming calculation process, and it can be done just by directly accessing the results that are already stored in the simulation database 202. In this case, it should be noted that the cost constants 103 are calculated in the required function evaluation 102 using the result of the check. This breakdown of the required function in accordance with equation (1) ensures that, even if the cost constants were to change, the required function can be calculated (and optimized) quickly and efficiently, with no need to make use of the simulator 106 once again for the sets of the parameters x that have already been determined.

Figure 3 shows an automated method for systematic use of the simulation database 202. Using grid sampling 301, it is possible to determine results y directly for specific (multidimensional) points x in parameter space, deliberately via the simulation interface 201, the power station link 105 and the simulator 106, and to store these results in the simulation database. The advantage is that the use of the systematically determined points results in a "grid" of greater or lesser density, depending on the application. This grid makes it possible to determine intermediate values by interpolation or extrapolation, without any need for a check with the simulator 106. The grid thus results in a basic structure which can be helpful for further optimization, even without the simulator 106.

Figure 4 shows the situation once grid sampling has been completed. Here, there is no longer any need for the simulator 106 (indicated by the interrupted

connecting line 402). A simulation and/or optimization process can thus be carried out, for example, without any link to the simulator 106 and without its time-consuming calculations. A block 401 denotes the evaluation of the results which have been gathered in the simulation database and/or have been interpolated or extrapolated.

Configuration optimization of power stations

The process of optimizing the configuration of gas and steam power stations includes ~~comprises~~ a search for configuration points which lead to minimum power generation costs. The power generation costs form the required function f whose minimum is being looked for. The power generation costs now

depend not only on the power station variables to be configured (= parameters, setting parameters) which are combined in the following text within the variable vector x. In fact, this functional relationship includes a range of setting constants (in this case, cost constants, cost parameters; for example gradients of cost curves). Depending on the value of these cost constants, they may in some circumstances result in other design optima x_{opt} for the technical system, in this case the gas and steam power station.

Now, the values of these cost constants

a) cannot be determined exactly in most cases, that is to say they are subject to an uncertainty (which in general can be estimated only roughly),

and

b) in some cases (for example the fuel price) are not universally valid for all power station quotations at a given time, but vary regionally.

In order to assess a design optimum, it is important to be able to estimate whether this design optimum, which has been determined on the assumption of a specific value k_0 (referred to as the primary value in the following text) of the cost parameter k, and which is thus denoted x_{k0}, is also still optimum for adjacent values $k_0 \pm \Delta k$. The procedure for determining this **sensitivity of the design optimum to variation in the cost parameters** is described in detail in the following text.

In this case, two aspects are investigated:

1) How does the **design optimum** vary when one cost parameter is varied upward and downward by 50% about its primary value k_0?
   If the cost parameter k were to be varied continuously, then a curve x_k of design optima, configured by k, would be produced as the response to this question.

2) As sketched above, the power generation costs f depend on the design variables x and on the value of the cost parameter k:

$$f = f(x,k)$$

   (Only one cost parameter k is described here, for simplicity). The investigation described in 1) provides a functional relationship between the power generation costs and the cost parameter k,

which is obtained by selecting the configuration $X_{k_{present}}$, which is matched to $k_{present}$, for each present value of k:

$$f_{opt}(k_{present}) := (X_{k_{present}}, k_{present}).$$

However, in many cases, it is not desirable to match the configuration x to the value of the cost parameter k, instead of this, the configuration x_{k0} which has been optimized for the primary value k_0 should be retained even if the cost conditions change, that is to say for one entire value interval

$$[k_0 - \Delta k, k_0 + \Delta k]$$

of the cost parameter k. This procedure results in a different functional relationship between the power generation costs and the value

$$k_{present} : f_{x_{k0}}(k_{present}) := f(X_{k0}, k_{present}).$$

Such definition of the configuration x_{k0} results, of course, in a certain amount of optimization potential remaining unused for a given value $k_{present}$. This optimization potential corresponds to the additional costs associated with a standard configuration x_{k0}, and is thus quantified (as a function of $k_{present}$) by:

$$f_{x_{k0}}(k_{present}) - f_{opt}(k_{present}).$$

The more detailed investigation of said aspects is based on the following procedure:

(i) To define a "standard configuration" x_{k0}, all the cost parameters are set to their primary value k_0. x_{k0} is the minimum of the required function

(= power generation costs) $f(x, k_0)$ [with k_0 constant].

(ii) Those cost parameters which are identified as being relevant are each investigated individually. In the process, all the other cost parameters are each fixed at their primary value, while the parameter to be investigated, referred to as k, is decreased in small steps δk within an interval

$$[k_0 - \Delta k,\ k_0 + \Delta k]$$

arranged symmetrically about its primary value k_0

$$k_{present} = k_0 - \Delta k,\ k_0 - \Delta k + \delta k,\ k_0 - \Delta k + 2 \cdot \delta k, \ldots, k_0, \ldots, k_0 + \Delta k.$$

The interval width is chosen to be (for virtually all the parameters k being investigated)

$$\Delta k = 50\% \cdot k_0,$$

and the grid step width is chosen to be

$$\delta k = 5\% \cdot k_0.$$

The following step (iii) is carried out for each of the grid values $k_{present}$.

(iii) Determine the optimum configuration $X_{k_{present}}$ matched to $k_{present}$ by minimizing the required function (= power generation costs) $f(x, k_{present})$ [with $k_{present}$ constant]. By substituting $x_{kpresent}$ or x_{k0} into the required function $f(., k_{present})$, calculate the values $f_{opt}(k_{present})$ or $f x_{k0}$ $(k_{present})$.

The sequence of the points $x_{kpresent}$ for all the grid steps with the k interval is a quantized version of the sought curve x_k of design optima [see aspect 1)].

Analogously, the sequence of the differences $f_{opt}(k_{present})$ - $f x_{k0}$ $(k_{present})$ represents a quantized version of the function "additional costs of choosing the standard configuration x_{k0}" (as a function of $k_{present}$) [see aspect 2)].

A practical example shows that 500 optimization calculations must be carried out to determine $x_{kpresent}$ in accordance with step (iii) for power station optimization with 25 cost parameters to be investigated, each of which has 20 grid steps. Bearing in mind that the computation time required per configuration optimization process is approximately one day, as a result of the numerous (several hundred) checks on the simulator 106 required for this purpose, it is less economic, for step (iii) to optimize each of

the design variables in the full real-value space. To overcome this, the search area is quantized, as is explained in the following text.

Grid concept

Determination of the independent degrees of freedom

Results from optimization calculations such as high-line plots of the required function for selected section planes through this multidimensional variable space lead to the conclusion that the design optimum in

the variable space defined above are not isolated points but form a multidimensional subvariety. This is in turn an indication that the design variables are not in fact all independent of one another but are, in some cases, linked to one another by physical relationships. The number of degrees of freedom for the optimization may thus be reduced.

As explained above, the movement of design optima is intended to be calculated in the course of the sensitivity analysis. Isolated optima rather than entire optimum varieties are required for this purpose. Further section planes in the above variable space are defined deliberately in order to determine the actually independent degrees of freedom for the gas and steam design. The analysis of the high-line plots of the power generation costs on these section planes frequently leads to the global optimum of the power generation costs being located - approximately - in a **reduced search area** (that is to say in a subarea of the variable space mentioned above).

Concept of a simulation database

Every evaluation of the required function $f(x, k_{present})$ is carried out in two stages:

(1) An entire range of thermodynamic and geometric variables is calculated for each check with the simulator 106 as a function of the value x of the design variables, characterizing one configuration. These variables are then combined to form the vector s for the simulation data: $s = s(x)$.

(2) The value of the required function (that is to say the power generation costs) is calculated from the simulation data $s(x)$ as a function of the cost parameter constellation $k_{present}$.

The concept of a simulation database subdivides the required function calculation into two mutually independent programs.

Program 1 Starts a check with the simulator 106 in each case for any predetermined variable points x_1, and stores the simulation results $s(x_i)$ in the simulation database 202, which is preferably in the form of a file with a specific format. The cost parameters are irrelevant to this program.

Program 2 Calculates the value of the required function $f(x, k_{present})$ for a given cost parameter constellation $k_{present}$, for all the simulation data s stored in the simulation database 202 - and hence for all the variable values x on which this simulation data is based.

In combination with the grid concept, this results in the following procedure:

- The program 1 is used to apply grid points to the simulation database in advance.

- The required function values $f(x, k_{present})$ of all the grid points are calculated by means of the program 2 for each cost parameter constellation $k_{present}$ to be calculated. The grid point having the minimum required function value is noted as the optimum.

Significance of the cost parameters

The aim, for example, of the design optimization process is to minimize the power generation costs:

$$\text{Power generation costs} = \frac{\text{Investment costs} \times \text{Annuity}}{P_{elec,\ gas\ and\ steam,net} \times h_{year}} + \frac{b}{\eta_{gas\ and\ steam}}$$

The term "investment costs" is formed from the costs of the three individual aspects which are mainly affected by the design decisions,

- cold end,
- steam turbine,
- hot surfaces of the waste heat boiler and

- the costs of the remaining power station parts, which are referred to in summary form as "remainder of power station":

$$\text{Investment costs} = \text{Costs}_{\text{Cold end}} + \text{Costs}_{\text{Turbine}} + \text{Costs}_{\text{Hot surfaces of the waste heat boiler, gas and steam}} + \text{Costs}_{\text{Remainder of power station}}$$

Further reorganization of these individual investment cost terms result in those cost parameters becoming visible which influence these cost terms - in conjunction with the design variables:

(A) Cold end

$$\text{Costs}_{\text{Cold end}} = \text{Costs}_{\text{Cooling system: pipes/pumps}} + \text{Costs}_{\text{condensor}} + \text{Costs}_{\text{Cooling tower}}$$

$$\text{Costs}_{\text{Cooling system: pipes/pumps}} = m_{\text{cooling water}} \times \mathbf{Price}_{\mathbf{kg/s,Cooling\ water}} + \text{Basic price}_{\text{Cooling system: pipes/pumps}}$$

$$\text{Costs}_{\text{Condensor}} = \text{Area}_{\text{Condensor}} \times \mathbf{Price}_{\mathbf{m^2,Condensor}} + \text{Basic price}_{\text{Condensor}}$$

$$\text{Costs}_{\text{Cooling tower}} = \text{Basic area}_{\text{Cooling tower}} \times \mathbf{Price}_{\mathbf{m^2,Cooling\ tower}} + \text{Basic price}_{\text{Cooling tower}}$$

The costs of the cold end are thus critically influenced by the values of the following three cost parameters:

- specific costs of the cooling system ($\text{Price}_{\text{kg/s,Cooling water}}$),
- price per square meter of condensor area ($\text{Price}_{\text{m}^2\text{,Condensor}}$) and
- price per square meter of the cooling tower base area ($\text{Price}_{\text{m}^2\text{,Cooling tower}}$).

(B) Steam turbine

A linearization process is carried out around a reference design point in order to model how the costs of the steam turbine depend on the HD temperature and the HD pressure:

$$\mathrm{Costs}_{\mathrm{Turbine}} = \mathbf{Costs}_{\mathbf{Turbine,reference}} \times (1 + \mathrm{Correctionsummand}_{\mathrm{Turbine},\Delta p} + \mathrm{Correctionsummand}_{\mathrm{Turbine},\Delta T})$$

$\text{Correctionsummand}_{\text{Turbine},\Delta T}$

$= \mathbf{CorrTurb}_{\boldsymbol{\Delta T},\textbf{Gradient}} \times (T_{HD} = T_{HD,\text{Reference}})$

$\text{Correctionsummand}_{\text{Turbine},\Delta p} = \mathbf{CorrTurb}_{\boldsymbol{\Delta p},\textbf{Gradient}} \times (p_{HD} - p_{HD,\text{Reference}})$

The turbine costs thus depend on the following three cost parameters

- turbine costs for the reference design ($\text{Costs}_{\text{Turbine},\text{Reference}}$),
- temperature dependency on the turbine costs ($\text{CorrTurb}_{\Delta T,\text{Gradient}}$),
- pressure dependency of the turbine costs ($\text{CorrTurb}_{\Delta p,\text{Gradient}}$).

(C) Heating surfaces

The costs for the individual boilers (which are physically identical) must be added up in order to obtain the costs for the total heating surfaces of a multishaft system:

$\text{Costs}_{\text{Heating surface,gas and steam}} = \text{Costs}_{\text{Heating surface,Boiler}} \times \text{Number}_{\text{Boilers}}$

The costs of an individual boiler are composed of:

- a lump sum, the cost parameter "lump sum for the heating surface costs per waste heat boiler ($\text{Costs}_{\text{Heating surface,fixed}}$)" and
- the contributions of the individual heating surfaces, which are dependent on the heating surface geometry, the materials used and the wall fittings, which depend on the boiler shape.

The costs of the individual heating surfaces are each influenced by the two cost parameters:

- basic price of the heating surfaces per square meter ($Price_{Heating\ surface,m^2}$) and
- price of the heating surface tubes per kilogram ($Price_{Heating\ surface,kg}$).

$$Costs_{Heating\ surface,Boiler} = \mathbf{Costs_{Heating\ surface,fixed}} + \sum_{Heating\ surface\ i} Costs_{Heating\ surface\ i}\ \mathbf{(Price_{Heating\ surface,m2},\ Price_{Heating\ surface,kg})}$$

Both the basic square-meter price and the kilogram price are dependent on the materials.

(D) Remainder of the power station

The costs of the remainder of the power station can be modeled in at least two different ways:

(i) As proportional to the net total output of the power station;
Since the investment costs are divided by the net total output in the formula for the power generation costs, this approach results in only one constant which is the same for all design variants, that is to say the costs of the remainder of the power station are irrelevant to the optimization.

(ii) As an output-independent lump sum;
If this approach is chosen, the costs of the remainder of the power station are highly significant to the design optimization since, if the power station output is relatively large, the lump sum (converted to a per annum rate) is distributed over a relatively large number of kWh.

Certain parts of the remainder of the power station are modeled more appropriately by approach (i), and others by approach (ii), but the precise breakdown can be determined only with great difficulty:

$$\text{Costs}_{\text{Remainder of the power station}} = \text{Costs}_{\text{per kW}} \times P_{\text{elec, gas and steam, net}} + \textbf{Costs}_{\textbf{Remainder of the power station,constant}}$$

The three location-specific parameters:

- annuity,
- annual operating hours (h_{year}) and
- fuel costs per kWh combustion heat (b)

are investigated as the final group of cost parameters which, within the required function, govern the ratio between the investment cost and fuel cost proportion of the power generation costs.

Processor unit

Figure 5 shows a processor unit PRZE which is suitable for carrying out any of the previously expressed methodology, including transformation and/or compression/decompression. The processor unit PRZE has a processor CPU, a memory MEM and an

input/output interface IOS, which is used in various ways via an interface IFC: an output can be displayed on a monitor MON and/or can be printed out on a printer PRT via a graphics interface. Inputs are made via a mouse MAS or a keyboard TAST. The processor unit PRZE also has a data bus BUS, which provides the connection from a memory MEM, the processor CPU and the input/output interface IOS. Additional components can also be connected to the data bus BUS, such as additional memory, data memory (hard disk) or a scanner. ¶ In addition, any of the aforementioned or other memory devices can ~~make~~ up a computer program product including program segments (article of manufacture), for carrying out any of the aforementioned methodology. Of course, such a computer program product can include any type of computer readable medium.

Such a computer program or processor product preferably is adapted to cause a computer to carry out steps of the aforementioned methodology,

VARIATIONS ¶

MARKED-UP CLAIMS

GR 99 P 2862

What is claimed is:
~~Patent Claims~~

1. (Amended) A method for simulation of a technical system, [(a)] in which a [required] function depends on parameters and on [predetermined] setting constants[;], comprising:

[(b) in which] determining a result in the form of an influence of the parameters on the technical system, [is determined] as a function of a [predetermined] set of parameters and on the basis of a request to an external source;

[(c) in which] temporarily storing [the result is temporarily stored]; and

[(d) in which] simulating the technical system [is simulated] on the basis of the result and of the setting constants.

2. (Amended) The method as claimed in claim 1, further comprising:
[in which the] designing the technical system [is designed] on the basis of the simulation.

3. (Amended) The method as claimed in claim 2, wherein [in which] the design process [comprises] includes at least one of an adaptation of, a change to, [or] and a redesign of the technical system.

4. (Amended) The method as claimed in claim 1 [one of the preceding claims], further comprising:
[in which] redetermining the influence of the parameters on the technical system [is redetermined] by accessing the temporarily stored result.

5. (Amended) The method as claimed in claim 1 [one of the preceding claims], wherein
[in which] the influence of each of a [large number] plurality of sets of parameters on the technical system is determined by checking the external source, and wherein the result of this check is temporarily stored.

(Amended)
6. The method as claimed in claim 5, wherein [in which] an additional influence is determined on the basis of the temporarily stored results.

(Amended)
7. The method as claimed in claim 6, [in which] wherein the additional influence is determined by at least one of interpolation [or] and extrapolation.

(Amended)
8. The method as claimed in claim 6, [in which] wherein the additional influence is determined from the results using an neural network.

9. (Amended) The method as claimed in claim 1 one of the preceding claims, wherein in which the external source is at least one of a simulator or and an experiment.

10. (Amended) The method as claimed in claim 1 one of the preceding claims, in which wherein the simulation is carried out using a large number plurality of results, without the external source.

11. (Amended) The method as claimed in claim 1 one of the preceding claims, further comprising: ~~wherein~~ determining, from in which the simulation of the technical system is used to determine, the sensitivity of sets of parameters to changes in the setting constants.

12. (Amendment) An arrangement for simulation of a technical system, comprising:
in which a processor unit is provided, which is set up such that: wherein,
(a) a required function depends on parameters and predetermined setting constants(;), wherein
(b) the processor unit is adapted to determine ~~a result in the~~ form of an influence of the parameters on the technical system can be determined as a function of a predetermined set of parameters and on the basis of a request to an external source; and
(c) a memory, adapted to temporarily the result can be temporarily stored; and, wherein
(d) the processor is adapted to simulate the technical system can be simulated on the basis of the result and of the setting constants.

13. (Amended) A computer program product for simulation of, adapted to cause a processor unit to simulate a technical system, which, when run on a processor unit, comprises the following steps: wherein
(a) a required function depends on parameters and predetermined setting constants(;), comprising:

first program segment, adapted to cause the processor unit to determine a

[(b)] a result, in the form of an influence of the parameters on the technical system, [is determined] as a function of a [predetermined] set of parameters and on the basis of a request to an external source;

a second program segment, adapted to cause the processor unit to ~~cause~~

[(c)] the result [is] to be temporarily stored; and

[(d)] the technical system [is simulated] on the basis of the result and of the setting constants.

a third program segment, adapted to cause the processor unit to simulate

NEW

14. same as 4, but dep on 2
15. same as 4, but dep on 3
16. same as 5, but dep on 2
17. same as 6, but dep on 16
18. same as 7, but dep on 17
19. same as 8, but dep on 17
20. same as 9, but dep on 2
21. same as 10, but dep on 2
22. same as 11, but dep on 2

23. The arrangement of claim 12, wherein the processor unit is further adapted to design the technical system on the basis of the simulation.

24. The arrangement of claim 23, [cl. 3]

25. The arrangement of claim 12, wherein the processor unit is further adapted to [cl. 4]

26. The arrangement of claim 12, [cl. 5]

27. The arrangement of claim 26, [cl. 6]

28. " " 27, [cl. 7]

29. " " 27, [cl. 8]

30. " " 12, [cl. 9]

31. " " 12, [cl. 10]

32. The arrangement of claim 12, wherein the processor unit is further adapted to determine, [cl. 11]

33. The computer program product of claim 13, ~~wh~~ including a computer readable medium.

34. The computer program product of claim 13, further comprising a fourth program segment, adapted to cause the processor unit to design [cl. 2]

35. The computer program product of claim 34, [cl. 3]

36. The computer program product of claim 13, further comprising a fourth program segment, adapted to cause the processor unit to redetermine [cl. 4]

37. The computer program product of claim 13, [cl. 5]

38. " " 37 [cl. 6]

39. " " 38 [cl. 7]

40. " " 38 [cl. 8]

41. " " 13 [cl. 9]

42. computer program product of [same as cl. 36, except "determine" + insert cl. 11 (not cl. 4)] 13 [cl. 10]

MARKED-UP ABSTRACT

Abstract

~~**Method, arrangement and computer program product for simulation of a technical system**~~

A method is specified for simulation of a technical system, in which a required function depends on parameters and predetermined setting constants. A result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source. The result is temporarily stored. The technical system is simulated on the basis of the result and of the setting constants.

New Application
Docket No. 32860-000282/US

SUBSTITUTE SPECIFICATION

METHOD, ARRANGEMENT AND PRODUCT OF A COMPUTER PROGRAM FOR SIMULATING A TECHNICAL SYSTEM

[0001] This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/DE00/03143 which has an International filing date of September 11, 2000, which designated the United States of America, the entire contents of which are hereby incorporated by reference.

Field of the Invention

[0002] The invention generally relates to a method, an arrangement and a computer program product for simulation of a technical system.

Background of the Invention

[0003] Various approaches are known (see [1] for example), for optimization of a technical system, in particular for global optimization. If the system to be optimized is a complex structure which is difficult to describe analytically, or cannot be described at all, then a simulation is frequently carried out for a specific configuration of the technical system. In a simulation such as this, a configuration or a reaction of the technical system is calculated as a function of a large number of setting parameters. Since there are a large number of setting parameters and an immense number of computation operations involved in determining the configuration of the technical system for specific sets of setting parameters, this involves an enormous amount of computation effort. If all the possible setting parameters of interest are combined to form a so-called parameter vector x, then this results in a simulation response y of dimension m for each case of this parameter vector in a dimension n.

[0004] For (global) optimization, as good a configuration as possible, or as good a setting as possible, of the technical system is determined for a required function *f*. However, in addition to the setting parameters which are provided for the technical system and which can be varied during an optimization calculation, it is now also possible for so-called setting constants to occur which cannot be varied in a corresponding manner during the optimization calculation, and which are thus not variables (= can be varied) for optimization purposes. Nevertheless, these setting constants are of major importance since they influence the required function. One example of such setting constants is cost constants which, in some circumstances, vary severely, to a greater or lesser extent, over the course of time. If the cost constants change beyond a certain amount, and assuming that the required function includes costs, this may result in a change in the result during the course of the optimization process. It is now a major

disadvantage to have to carry out the simulation process once again, as described above, if the cost constants change, thus resulting in the enormous computation effort being incurred once again.

SUMMARY OF THE INVENTION

[0005] An object of an embodiment of the invention is to allow a technical system to be simulated without having to carry out unnecessary time-consuming simulation steps more than once.

[0006] This object can be achieved, for example, by a method for simulation of a technical system.

[0007] In order to achieve such an object, an embodiment of the invention specifies a method for simulation of a technical system, in which a required function depends on parameters and predetermined setting constants. A result in the form of an influence of the parameters on the technical system can be determined as a function of a predetermined set of parameters and on the basis of a request to an external source. The result can be temporarily stored. The technical system can be simulated on the basis of the result and the setting constants.

[0008] In this case, it can be particularly advantageous that the process of determining the value of the required function can be split into determination of the influence of the parameters on the technical system and determination of the influence of the setting constants on the technical system. It can thus be possible to optimize the time-consuming and computation-intensive check with the external source such that, in particular, once results have been determined, they can be reused for further simulation purposes.

[0009] One development can include the technical system being designed on the basis of the simulation. In particular, in this case, the technical system can be

- redesigned,
- adapted,
- configured, or
- controlled.

[0010] Redesign preferably includes recreation of the technical system, for example of a process technology system, of a circuit or of a software system. Adaptation can include a change to an existing system, for example in order to improve its operation. Configuration may include defining not only the sizes but also settings of components, for example of physical dimensions of parts of a technical system. Finally, control allows the variable system parameters to be set efficiently so that, in particular, it is possible to ensure that it operates as efficiently as possible.

[0011] One refinement can be for the influence of the parameters of the technical system to be redetermined by accessing the temporarily stored result. This temporary storage step saves a considerable amount of computation effort and time.

[0012] Another development can be to determine the influence of each of a large number of sets of parameters on the technical system by checking with the external source, and then temporarily store the result of this check. In this case, it is advantageous that a number of checks result in a number of results, whose temporary storage defines a (multidimensional) plane in a (multidimensional) space. This plane is defined with greater accuracy, the greater the number of checks that are carried out with the external source (for example the simulator). If the plane has been defined sufficiently accurately, that is to say it has a sufficient number of support points, then further (multidimensional) points on the same plane can be determined by interpolation or extrapolation, even without any checks. Such an interpolation/extrapolation method is generally considerably less time-consuming and computation-intensive than the determination process by means of a simulator.

[0013] In one development, a number of results can also be initially determined and can be temporarily stored. Additional points can then be determined without any further check with the external source by means of a neural network, with the stored results being provided as a training set to the neural network. A neural network such as this may, in particular, be in the form of a multilayer perceptron (see [2] for example).

[0014] The check with the external source may, in particular, be carried out so that the external source itself represents a complex simulation program, on the basis of which, and depending on the set of parameters, a result can be calculated for that configuration or more detailed description of the technical system. One alternative to this is to carry out the check with an external source via an experiment.

[0015] In another refinement, the simulation of the large number of results can be carried out without any further check with the external source. In particular, the temporarily stored multidimensional description of the results which have already been determined from checks that have been carried out can be used to carry out a further simulation without any need for the complex mechanism for determining the results in the form of the external source.

[0016] In an additional refinement, the method for simulation of a technical system as described above can be used in a sensitivity analysis. In this case, the sensitivity of the optima (the variable parameters) to changes to the predetermined setting constants is determined.

[0017] Furthermore, in order to achieve an object, an arrangement for simulation of a technical system can be specified, in which a processor unit is provided which can be set up such that:

1. a required function depends on parameters and predetermined setting constants;
2. a result in the form of an influence of the parameters on the technical system can be determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
3. the result can be temporarily stored; and
4. the technical system can be simulated on the basis of the result and of the setting constants.

[0018] Furthermore, a computer program product (article of manufacture) can be specified in order to achieve an object, which is intended for simulation of a technical system and, when run on a processor unit, includes the following steps:

1. a required function depends on parameters and predetermined setting constants;
2. a result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
3. the result is temporarily stored; and
4. the technical system is simulated on the basis of the result and of the setting constants.

[0019] The arrangement and the computer program product are particularly suitable for carrying out the method according to an embodiment of the invention, and/or one ore more of its developments explained above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Exemplary embodiments of the invention will be described and explained in the following text with reference to the drawings, in which:

Figure 1 shows a method for simulation of a technical system;

Figure 2 shows a method for simulation of a technical system with a temporary store;

Figure 3 shows a method for simulation of a technical system with automatic grid sampling;

Figure 4 shows a method for simulation using a simulation database; and

Figure 5 shows a processor unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] **Figure 1** shows a method for simulation of a technical system, in particular of a power station. Required function evaluation 102 depends on the results from external sources, in this case an external simulator 106 which is linked via a "power station link" interface 105.

Furthermore, the required function evaluation 102 depends on setting constants, in this case cost constants 103. This thus results in the following relationship:

$$f_{\alpha,\beta,\ldots}(\mathbf{x}) = F_{\alpha,\beta,\ldots} \circ \underbrace{\phi(\mathbf{x})}_{\mathbf{y}\in\mathbb{R}^{n+m}}, \mathbf{x} \in \mathbb{R}^n. \quad (1)$$

[0022] Here, f denotes the required function, which depends on the cost constants α, β, ... and is split into a component F, which includes the cost constants, into a component ϕ, which comprises the parameters $x = (x_1, x_2, \ldots, x_n)^T$, which can be influenced during the course of the optimization process. The character "O" in the above formula (1) denotes that two functions are carried out successively.

[0023] A (global) optimization of the required function f, which is provided by the required function evaluation 102, is carried out in an optimization process 101. The result of the optimization process 101 is used, in particular, for a new entry into the required function, so that another optimization process 101 can be carried out taking into account the cost constants 103. In particular, this method is reiterated until a predetermined quality has been achieved, or the further improvement between the most recent iterations is not significant. Results from the required function evaluation 102 are preferably stored in a record file 104.

[0024] **Figure 2** is an expansion of Figure 1, in which a simulation interface 201 with a simulation database 202 is inserted. The simulation interface 201 means that the result of each check with an external source, in this case via the power station link 105 and the simulator 106, is temporarily stored in the simulation database. If the same check with the simulator 106 were to occur at a later time, then there is no need for this to start another time-consuming calculation process, and it can be done just by directly accessing the results that are already stored in the simulation database 202. In this case, it should be noted that the cost constants 103 are calculated in the required function evaluation 102 using the result of the check. This breakdown of the required function in accordance with equation (1) ensures that, even if the cost constants were to change, the required function can be calculated (and optimized) quickly and efficiently, with no need to make use of the simulator 106 once again for the sets of the parameters x that have already been determined.

[0025] **Figure 3** shows an automated method for systematic use of the simulation database 202. Using grid sampling 301, it is possible to determine results y directly for specific (multidimensional) points x in parameter space, deliberately via the simulation interface 201, the power station link 105 and the simulator 106, and to store these results in the simulation

database. The advantage is that the use of the systematically determined points results in a "grid" of greater or lesser density, depending on the application. This grid makes it possible to determine intermediate values by interpolation or extrapolation, without any need for a check with the simulator 106. The grid thus results in a basic structure which can be helpful for further optimization, even without the simulator 106.

[0026] Figure 4 shows the situation once grid sampling has been completed. Here, there is no longer any need for the simulator 106 (indicated by the interrupted connecting line 402). A simulation and/or optimization process can thus be carried out, for example, without any link to the simulator 106 and without its time-consuming calculations. A block 401 denotes the evaluation of the results which have been gathered in the simulation database and/or have been interpolated or extrapolated.

Configuration optimization of power stations

[0027] The process of optimizing the configuration of gas and steam power stations includes a search for configuration points which lead to minimum power generation costs. The power generation costs form the required function f whose minimum is being looked for. The power generation costs now depend not only on the power station variables to be configured (= parameters, setting parameters) which are combined in the following text within the variable vector x. In fact, this functional relationship includes a range of setting constants (in this case, cost constants, cost parameters; for example gradients of cost curves). Depending on the value of these cost constants, they may in some circumstances result in other design optima x_{opt} for the technical system, in this case the gas and steam power station.

[0028] Now, the values of these cost constants

a) cannot be determined exactly in most cases, that is to say they are subject to an uncertainty (which in general can be estimated only roughly),

and

b) in some cases (for example the fuel price) are not universally valid for all power station quotations at a given time, but vary regionally.

[0029] In order to assess a design optimum, it is important to be able to estimate whether this design optimum, which has been determined on the assumption of a specific value k_0

(referred to as the primary value in the following text) of the cost parameter k, and which is thus denoted x_{k0}, is also still optimum for adjacent values $k_0 \pm \Delta k$. The procedure for determining this **sensitivity of the design optimum to variation in the cost parameters** is described in detail in the following text.

[0030] In this case, two aspects are investigated:

1) How does the **design optimum** vary when one cost parameter is varied upward and downward by 50% about its primary value k_0?

If the cost parameter k were to be varied continuously, then a curve x_k of design optima, configured by k, would be produced as the response to this question.

2) As sketched above, the power generation costs f depend on the design variables x and on the value of the cost parameter k:

$$f = f(x,k)$$

(Only one cost parameter k is described here, for simplicity). The investigation described in 1) provides a functional relationship between the power generation costs and the cost parameter k,

which is obtained by selecting the configuration $X_{k_{present}}$, which is matched to $k_{present}$, for each present value of k:

$$f_{opt}(k_{present}) := (X_{k_{present}}, k_{present}).$$

However, in many cases, it is not desirable to match the configuration x to the value of the cost parameter k, instead of this, the configuration x_{k_0} which has been optimized for the primary value k_0 should be retained even if the cost conditions change, that is to say for one entire value interval

$$[k_0 - \Delta k, k_0 + \Delta k]$$

of the cost parameter k. This procedure results in a different functional relationship between the power generation costs and the value

$$k_{present} : f_{x_{k_0}}(k_{present}) := f(X_{k_0}, k_{present}).$$

Such definition of the configuration x_{k0} results, of course, in a certain amount of optimization potential remaining unused for a given value $k_{present}$. This optimization potential corresponds to the additional costs associated with a standard configuration x_{k0}, and is thus quantified (as a function of $k_{present}$) by:

$$f_{x_{k0}}(k_{present}) - f_{opt}(k_{present}).$$

[0031] The more detailed investigation of said aspects is based on the following procedure:

(i) To define a "standard configuration" x_{k0}, all the cost parameters are set to their primary value k_0. x_{k0} is the minimum of the required function (= power generation costs) $f(x, k_0)$ [with k_0 constant].

(ii) Those cost parameters which are identified as being relevant are each investigated individually. In the process, all the other cost parameters are each fixed at their primary value, while the parameter to be investigated, referred to as k, is decreased in small steps δk within an interval

$$[k_0 - \Delta k, k_0 + \Delta k]$$

arranged symmetrically about its primary value k_0

$$k_{present} = k_0 - \Delta k, k_0 - \Delta k + \delta k, k_0 - \Delta k + 2 \cdot \delta k, \ldots, k_0, \ldots, k_0 + \Delta k.$$

The interval width is chosen to be (for virtually all the parameters k being investigated)

$$\Delta k = 50\% \cdot k_0,$$

and the grid step width is chosen to be

$$\delta k = 5\% \cdot k_0.$$

The following step (iii) is carried out for each of the grid values $k_{present}$.

(iii) Determine the optimum configuration $x_{k_{present}}$ matched to $k_{present}$ by minimizing the required function (= power generation costs) $f(x,k_{present})$ [with $k_{present}$ constant]. By

substituting $x_{kpresent}$ or x_{k0} into the required function $f(.,k_{present})$, calculate the values $f_{opt}(k_{present})$ or $f\,x_{k0}\,(k_{present})$.

The sequence of the points $x_{kpresent}$ for all the grid steps with the k interval is a quantized version of the sought curve x_k of design optima [see aspect 1)].
Analogously, the sequence of the differences $f_{opt}(k_{present})$ - $f\,x_{k0}\,(k_{present})$ represents a quantized version of the function "additional costs of choosing the standard configuration x_{k0}" (as a function of $k_{present}$) [see aspect 2)].

[0032] A practical example shows that 500 optimization calculations must be carried out to determine $x_{kpresent}$ in accordance with step (iii) for power station optimization with 25 cost parameters to be investigated, each of which has 20 grid steps. Bearing in mind that the computation time required per configuration optimization process is approximately one day, as a result of the numerous (several hundred) checks on the simulator 106 required for this purpose, it is less economic, for step (iii) to optimize each of the design variables in the full real-value space. To overcome this, the search area is quantized, as is explained in the following text.

Grid concept

Determination of the independent degrees of freedom

[0033] Results from optimization calculations such as high-line plots of the required function for selected section planes through this multidimensional variable space lead to the conclusion that the design optimum in the variable space defined above are not isolated points but form a multidimensional subvariety. This is in turn an indication that the design variables are not in fact all independent of one another but are, in some cases, linked to one another by physical relationships. The number of degrees of freedom for the optimization may thus be reduced.

[0034] As explained above, the movement of design optima is intended to be calculated in the course of the sensitivity analysis. Isolated optima rather than entire optimum varieties are required for this purpose. Further section planes in the above variable space are defined deliberately in order to determine the actually independent degrees of freedom for the gas and steam design. The analysis of the high-line plots of the power generation costs on these section planes frequently leads to the global optimum of the power generation costs being located - approximately - in a **reduced search area** (that is to say in a subarea of the variable space mentioned above).

Concept of a simulation database

[0035] Every evaluation of the required function $f(x,k_{present})$ is carried out in two stages:

(1) An entire range of thermodynamic and geometric variables is calculated for each check with the simulator 106 as a function of the value x of the design variables, characterizing one configuration. These variables are then combined to form the vector s for the simulation data: s = s(x).

(2) The value of the required function (that is to say the power generation costs) is calculated from the simulation data s(x) as a function of the cost parameter constellation $k_{present}$.

[0036] The concept of a simulation database subdivides the required function calculation into two mutually independent programs.

Program 1 Starts a check with the simulator 106 in each case for any predetermined variable points x_i, and stores the simulation results $s(x_i)$ in the simulation database 202, which is preferably in the form of a file with a specific format. The cost parameters are irrelevant to this program.

Program 2 Calculates the value of the required function $f(x, k_{present})$ for a given cost parameter constellation $k_{present}$, for all the simulation data s stored in the simulation database 202 - and hence for all the variable values x on which this simulation data is based.

[0037] In combination with the grid concept, this results in the following procedure:

- The program 1 is used to apply grid points to the simulation database in advance.
- The required function values $f(x, k_{present})$ of all the grid points are calculated by means of the program 2 for each cost parameter constellation $k_{present}$ to be calculated. The grid point having the minimum required function value is noted as the optimum.

Significance of the cost parameters

[0038] The aim of the design optimization process is to minimize, for example, the power generation costs:

$$\text{Power generation costs} = \frac{\text{Investment costs} \times \text{Annuity}}{P_{elec,\ gas\,and\,steam,net} \times h_{year}} + \frac{b}{\eta_{gas\ and\ steam}}$$

[0039] The term "investment costs" is formed from the costs of the three individual aspects which are mainly affected by the design decisions,

- cold end,
- steam turbine,
- hot surfaces of the waste heat boiler and the costs of the remaining power station parts, which are referred to in summary form as "remainder of power station":

$$\text{Investment costs} = \text{Costs}_{\text{Cold end}} + \text{Costs}_{\text{Turbine}}$$
$$+ \text{Costs}_{\text{Hot surfaces of the waste heat boiler, gas and steam}}$$
$$+ \text{Costs}_{\text{Remainder of power station}}$$

[0040] Further reorganization of these individual investment cost terms result in those cost parameters becoming visible which influence these cost terms - in conjunction with the design variables:

(A) Cold end

$$\text{Costs}_{\text{Cold end}} = \text{Costs}_{\text{Cooling system: pipes/pumps}} + \text{Costs}_{\text{condensor}}$$
$$+ \text{Costs}_{\text{Cooling tower}}$$

$$\text{Costs}_{\text{Cooling system: pipes/pumps}} = m_{\text{cooling water}} \times \mathbf{Price}_{\mathbf{kg/s,Cooling\ water}}$$
$$+ \text{Basic price}_{\text{Cooling system: pipes/pumps}}$$

$$\text{Costs}_{\text{Condensor}} = \text{Area}_{\text{Condensor}} \times \mathbf{Price}_{\mathbf{m^2,Condensor}}$$
$$+ \text{Basic price}_{\text{Condensor}}$$

$$\text{Costs}_{\text{Cooling tower}} = \text{Basic area}_{\text{Cooling tower}} \times \mathbf{Price}_{\mathbf{m^2,Cooling\ tower}}$$
$$+ \text{Basic price}_{\text{Cooling tower}}$$

The costs of the cold end are thus critically influenced by the values of the following three cost parameters:

- specific costs of the cooling system ($\text{Price}_{\text{kg/s,Cooling water}}$),
- price per square meter of condensor area ($\text{Price}_{\text{m}^2\text{,Condensor}}$) and
- price per square meter of the cooling tower base area ($\text{Price}_{\text{m}^2\text{,Cooling tower}}$).

(B) Steam turbine

A linearization process is carried out around a reference design point in order to model how the costs of the steam turbine depend on the HD temperature and the HD pressure:

$$\text{Costs}_{\text{Turbine}} = \mathbf{Costs}_{\mathbf{Turbine,reference}}$$

$\times (1 + \text{Correctionsummand}_{\text{Turbine},\Delta p}$
$+ \text{Correctionsummand}_{\text{Turbine},\Delta T})$
$\text{Correctionsummand}_{\text{Turbine},\Delta T}$
$= \mathbf{CorrTurb}_{\mathbf{\Delta T,Gradient}} \times (T_{HD} = T_{HD,\text{Reference}})$

$\text{Correctionsummand}_{\text{Turbine},\Delta p} = \mathbf{CorrTurb}_{\mathbf{\Delta p,Gradient}} \times (p_{HD} - p_{HD},\text{Reference})$

The turbine costs thus depend on the following three cost parameters

- turbine costs for the reference design ($\text{Costs}_{\text{Turbine,Reference}}$),
- temperature dependency on the turbine costs ($\text{CorrTurb}_{\Delta T,\text{Gradient}}$),
- pressure dependency of the turbine costs ($\text{CorrTurb}_{\Delta p,\text{Gradient}}$).

(C) Heating surfaces

The costs for the individual boilers (which are physically identical) must be added up in order to obtain the costs for the total heating surfaces of a multishaft system:

$\text{Costs}_{\text{Heating surface,gas and steam}} = \text{Costs}_{\text{Heating surface,Boiler}} \times \text{Number}_{\text{Boilers}}$

The costs of an individual boiler are composed of:

- a lump sum, the cost parameter "lump sum for the heating surface costs per waste heat boiler ($\text{Costs}_{\text{Heating surface,fixed}}$)" and
- the contributions of the individual heating surfaces, which are dependent on the heating surface geometry, the materials used and the wall fittings, which depend on the boiler shape.

The costs of the individual heating surfaces are each influenced by the two cost parameters:

- basic price of the heating surfaces per square meter ($\text{Price}_{\text{Heating surface},m^2}$) and
- price of the heating surface tubes per kilogram ($\text{Price}_{\text{Heating surface,kg}}$).

$$\text{Costs}_{\text{Heating surface,Boiler}} = \mathbf{Costs}_{\mathbf{Heating\ surface,fixed}} + \sum_{\text{Heating surface } i} \text{Costs}_{\text{Heating surface } i}\,(\mathbf{Price}_{\mathbf{Heating\ surface,m2}}, \mathbf{Price}_{\mathbf{Heating\ surface,kg}})$$

Both the basic square-meter price and the kilogram price are dependent on the materials.

(D) Remainder of the power station

The costs of the remainder of the power station can be modeled in at least two different ways:

(i) As proportional to the net total output of the power station;
Since the investment costs are divided by the net total output in the formula for the power generation costs, this approach results in only one constant which is the same for all design variants, that is to say the costs of the remainder of the power station are irrelevant to the optimization.

(ii) As an output-independent lump sum;
If this approach is chosen, the costs of the remainder of the power station are highly significant to the design optimization since, if the power station output is relatively large, the lump sum (converted to a per annum rate) is distributed over a relatively large number of kWh.

Certain parts of the remainder of the power station are modeled more appropriately by approach (i), and others by approach (ii), but the precise breakdown can be determined only with great difficulty:

$$\mathrm{Costs}_{\text{Remainder of the power station}} = \mathrm{Costs}_{\text{per kW}} \times P_{\text{elec, gas and steam, net}} + \mathbf{Costs}_{\textbf{Remainder of the power station,constant}}$$

[0041] The three location-specific parameters:

- annuity,
- annual operating hours (h_{year}) and
- fuel costs per kWh combustion heat (b)

are investigated as the final group of cost parameters which, within the required function, govern the ratio between the investment cost and fuel cost proportion of the power generation costs.

Processor unit

[0042] **Figure 5** shows a processor unit PRZE which is suitable for carrying out any of the previously expressed methodology, including transformation and/or compression/decompression. The processor unit PRZE has a processor CPU, a memory

MEM and an input/output interface IOS, which is used in various ways via an interface IFC: an output can be displayed on a monitor MON and/or can be printed out on a printer PRT via a graphics interface. Inputs are made via a mouse MAS or a keyboard TAST. The processor unit PRZE also has a data bus BUS, which provides the connection from a memory MEM, the processor CPU and the input/output interface IOS. Additional components can also be connected to the data bus BUS, such as additional memory, data memory (hard disk) or a scanner.

[0043] In addition, any of the aforementioned or other memory devices can make up a computer program product including program segments (article of manufacture), for carrying out any of the aforementioned methodology. Of course, such a computer program can include any type of computer readable medium Such a computer program product preferably is adapted to cause a computer or processor to carry out steps of the aforementioned methodology.

[0044] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

List of references

[1] S. Schäffler: Global Optimization Using Stochastic Integration, Roderer-Verlag, Regensburg 1995.

[2] H. Ritter, T. Martinetz, K. Schulten: Neuronale Netze - Eine Einführung in die Theorie selbstorganisierender Netzwerke [Neural networks - An introduction to the theory of self-organizing networks], Addison-Wesley, 1990.

10/088644
JC13 Rec'd PCT/PTO 20 MAR 2002

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Description

Method, arrangement and computer program product for simulation of a technical system

The invention relates to a method, an arrangement and a computer program product for simulation of a technical system.

Various approaches are known [1] for optimization of a technical system, in particular for global optimization. If the system to be optimized is a complex structure which is difficult to describe analytically, or cannot be described at all, then a simulation is frequently carried out for a specific configuration of the technical system. In a simulation such as this, a configuration or a reaction of the technical system is calculated as a function of a large number of setting parameters. Since there are a large number of setting parameters and an immense number of computation operations involved in determining the configuration of the technical system for specific sets of setting parameters, this involves an enormous amount of computation effort. If all the possible setting parameters of interest are combined to form a so-called parameter vector x, then this results in a simulation response y of dimension m for each case of this parameter vector in a dimension n.

For (global) optimization, as good a configuration as possible, or as good a setting as possible, of the technical system is determined for a required function *f*. However, in addition to the setting parameters which are provided for the technical system and which can be varied during an optimization calculation, it is now also possible for so-called setting constants to occur which cannot be varied in a corresponding manner during the optimization calculation, and which are thus

not variables (= can be varied) for optimization purposes. Nevertheless, these setting constants are of major importance since they influence the required function. One example of such setting constants is cost constants which, in some circumstances, vary severely, to a greater or lesser extent, over the course of time. If the cost constants change beyond a certain amount, and assuming that the required function includes costs, this may result in a change in the result during the course of the optimization process. It is now a major disadvantage to have to carry out the simulation process once again, as described above, if the cost constants change, thus resulting in the enormous computation effort being incurred once again.

The object of the invention is to allow a technical system to be simulated without having to carry out unnecessary time-consuming simulation steps more than once.

This object is achieved according to the features of the independent patent claims. Developments are described in the dependent claims.

In order to achieve the object, the invention specifies a method for simulation of a technical system, in which a required function depends on parameters and predetermined setting constants. A result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source. The result is temporarily stored. The technical system is simulated on the basis of the result and the setting constants.

In this case, it is particularly advantageous that the process of determining the value of the required function is split into determination of the influence of the parameters on the technical system and determination of the influence of the setting constants on the technical system. It is thus possible to optimize the time-consuming and computation-intensive check with the external source such that, in particular, once results have been determined, they can be reused for further simulation purposes.

One development comprises the technical system being designed on the basis of the simulation. In particular, in this case, the technical system can be

- redesigned,
- adapted,
- configured, or
- controlled.

Redesign preferably comprises recreation of the technical system, for example of a process technology system, of a circuit or of a software system.

Adaptation comprises a change to an existing system, for example in order to improve its operation. Configuration may comprise defining not only the sizes but also settings of components, for example of physical dimensions of parts of a technical system. Finally, control allows the variable system parameters to be set efficiently so that, in particular, it is possible to ensure that it operates as efficiently as possible.

One refinement is for the influence of the parameters of the technical system to be redetermined by accessing the temporarily stored result. This temporary storage step saves a considerable amount of computation effort and time.

Another development is to determine the influence of each of a large number of sets of parameters on the technical system by checking with the external source, and then temporarily store the result of this check. In this case, it is advantageous that a number of checks result in a number of results, whose temporary storage defines a (multidimensional) plane in a (multidimensional) space. This plane is defined with greater accuracy, the greater the number of checks that are carried out with the external source (for example the simulator). If the plane has been defined sufficiently accurately, that is to say it has a sufficient number of support points, then further (multidimensional) points on the same plane can be determined by interpolation or extrapolation, even without any checks. Such an interpolation/extrapolation method is generally considerably less time-consuming and computation-intensive than the determination process by means of a simulator.

In one development, a number of results are also initially determined and are temporarily stored. Additional points can then be determined without any further check with the external source by means of a neural network, with the stored results being provided as a training set to the neural network. A neural network such as this may, in particular, be in the form of a multilayer perceptron (see [2]).

The check with the external source may, in particular, be carried out so that the external source itself represents a complex simulation program, on the basis

of which, and depending on the set of parameters, a result is calculated for that configuration or more detailed description of the technical system. One alternative to this is to carry out the check with an external source by means of an experiment.

In another refinement, the simulation of the large number of results is carried out without any further check with the external source. In particular, the temporarily stored multidimensional description of the results which have already been determined from checks that have been carried out can be used to carry out a further simulation without any need for the complex mechanism for determining the results in the form of the external source.

In an additional refinement, the method for simulation of a technical system as described above is used in a sensitivity analysis. In this case, the sensitivity of the optima (the

variable parameters) to changes to the predetermined setting constants is determined.

Furthermore, in order to achieve the object, an arrangement for simulation of a technical system is specified, in which a processor unit is provided which is set up such that:

1. a required function depends on parameters and predetermined setting constants;
2. a result in the form of an influence of the parameters on the technical system can be determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
3. the result can be temporarily stored; and
4. the technical system can be simulated on the basis of the result and of the setting constants.

Furthermore, a computer program product is specified in order to achieve the object, which is intended for simulation of a technical system and, when run on a processor unit, comprises the following steps:

1. a required function depends on parameters and predetermined setting constants;
2. a result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
3. the result is temporarily stored; and
4. the technical system is simulated on the basis of the result and of the setting constants.

The arrangement and the computer program product are particularly suitable for carrying out the method according to the invention, or one of its developments explained above.

Exemplary embodiments of the invention will be described and explained in the following text with reference to the drawings, in which:

Figure 1 shows a method for simulation of a technical system;

Figure 2 shows a method for simulation of a technical system with a temporary store;

Figure 3 shows a method for simulation of a technical system with automatic grid sampling;

Figure 4 shows a method for simulation using a simulation database; and

Figure 5 shows a processor unit.

Figure 1 shows a method for simulation of a technical system, in particular of a power station. Required function evaluation 102 depends on the results from external sources, in this case an external simulator 106 which is linked via a "power station link" interface 105. Furthermore, the required function evaluation 102 depends on setting constants, in this case cost constants 103. This thus results in the following relationship:

$$f_{\alpha,\beta,\ldots}(\mathbf{x}) = F_{\alpha,\beta,\ldots} \circ \underbrace{\phi(\mathbf{x})}_{\mathbf{y}\in\mathbb{R}^{n+m}}, \mathbf{x} \in \mathbb{R}^n. \qquad (1)$$

Here, f denotes the required function, which depends on the cost constants α, β, ... and is split into a component F, which includes the cost constants, into a component ϕ, which comprises the parameters $x = (x_1, x_2, \ldots, x_n)^T$, which can be influenced during the course of the optimization process. The character "O" in the above formula (1) denotes that two functions are carried out successively.

A (global) optimization of the required function f, which is provided by the required function evaluation 102, is carried out in an optimization process 101. The result of the optimization process 101 is used, in

particular, for a new entry into the required function, so that another optimization process 101 can be carried out taking into account the cost constants 103. In particular, this method is reiterated until a predetermined quality has been achieved, or the further improvement between the most recent iterations is not significant. Results from the required function evaluation 102 are preferably stored in a record file 104.

Figure 2 is an expansion of Figure 1, in which a simulation interface 201 with a simulation database 202 is inserted. The simulation interface 201

means that the result of each check with an external source, in this case via the power station link 105 and the simulator 106, is temporarily stored in the simulation database. If the same check with the simulator 106 were to occur at a later time, then there is no need for this to start another time-consuming calculation process, and it can be done just by directly accessing the results that are already stored in the simulation database 202. In this case, it should be noted that the cost constants 103 are calculated in the required function evaluation 102 using the result of the check. This breakdown of the required function in accordance with equation (1) ensures that, even if the cost constants were to change, the required function can be calculated (and optimized) quickly and efficiently, with no need to make use of the simulator 106 once again for the sets of the parameters x that have already been determined.

Figure 3 shows an automated method for systematic use of the simulation database 202. Using grid sampling 301, it is possible to determine results y directly for specific (multidimensional) points x in parameter space, deliberately via the simulation interface 201, the power station link 105 and the simulator 106, and to store these results in the simulation database. The advantage is that the use of the systematically determined points results in a "grid" of greater or lesser density, depending on the application. This grid makes it possible to determine intermediate values by interpolation or extrapolation, without any need for a check with the simulator 106. The grid thus results in a basic structure which can be helpful for further optimization, even without the simulator 106.

Figure 4 shows the situation once grid sampling has been completed. Here, there is no longer any need for the simulator 106 (indicated by the interrupted

connecting line 402). A simulation and/or optimization process can thus be carried out, for example, without any link to the simulator 106 and without its time-consuming calculations. A block 401 denotes the evaluation of the results which have been gathered in the simulation database and/or have been interpolated or extrapolated.

Configuration optimization of power stations

The process of optimizing the configuration of gas and steam power stations comprises a search for configuration points which lead to minimum power generation costs. The power generation costs form the required function f whose minimum is being looked for. The power generation costs now

depend not only on the power station variables to be configured (= parameters, setting parameters) which are combined in the following text within the variable vector x. In fact, this functional relationship includes a range of setting constants (in this case, cost constants, cost parameters; for example gradients of cost curves). Depending on the value of these cost constants, they may in some circumstances result in other design optima x_{opt} for the technical system, in this case the gas and steam power station.

Now, the values of these cost constants

a) cannot be determined exactly in most cases, that is to say they are subject to an uncertainty (which in general can be estimated only roughly),

and

b) in some cases (for example the fuel price) are not universally valid for all power station quotations at a given time, but vary regionally.

In order to assess a design optimum, it is important to be able to estimate whether this design optimum, which has been determined on the assumption of a specific value k_0 (referred to as the primary value in the following text) of the cost parameter k, and which is thus denoted x_{k0}, is also still optimum for adjacent values $k_0 \pm \Delta k$. The procedure for determining this **sensitivity of the design optimum to variation in the cost parameters** is described in detail in the following text.

In this case, two aspects are investigated:

[redacted]

1) How does the **design optimum** vary when one cost parameter is varied upward and downward by 50% about its primary value k_0?
   If the cost parameter k were to be varied continuously, then a curve x_k of design optima, configured by k, would be produced as the response to this question.

2) As sketched above, the power generation costs f depend on the design variables x and on the value of the cost parameter k:

$$f = f(x,k)$$

   (Only one cost parameter k is described here, for simplicity). The investigation described in 1) provides a functional relationship between the power generation costs and the cost parameter k,

which is obtained by selecting the configuration $X_{k_{present}}$, which is matched to $k_{present}$, for each present value of k:

$$f_{opt}(k_{present}) := (X_{k_{present}}, k_{present}).$$

However, in many cases, it is not desirable to match the configuration x to the value of the cost parameter k, instead of this, the configuration x_{k0} which has been optimized for the primary value k_0 should be retained even if the cost conditions change, that is to say for one entire value interval

$$[k_0 - \Delta k, k_0 + \Delta k]$$

of the cost parameter k. This procedure results in a different functional relationship between the power generation costs and the value

$$k_{present} : f_{x_{k0}}(k_{present}) := f(X_{k0}, k_{present}).$$

Such definition of the configuration x_{k0} results, of course, in a certain amount of optimization potential remaining unused for a given value $k_{present}$. This optimization potential corresponds to the additional costs associated with a standard configuration x_{k0}, and is thus quantified (as a function of $k_{present}$) by:

$$f_{x_{k0}}(k_{present}) - f_{opt}(k_{present}).$$

The more detailed investigation of said aspects is based on the following procedure:

(i) To define a "standard configuration" x_{k0}, all the cost parameters are set to their primary value k_0. x_{k0} is the minimum of the required function

(= power generation costs) $f(x, k_0)$ [with k_0 constant].

(ii) Those cost parameters which are identified as being relevant are each investigated individually. In the process, all the other cost parameters are each fixed at their primary value, while the parameter to be investigated, referred to as k, is decreased in small steps δk within an interval

$$[k_0 - \Delta k,\ k_0 + \Delta k]$$

arranged symmetrically about its primary value k_0

$$k_{present} = k_0 - \Delta k,\ k_0 - \Delta k + \delta k,\ k_0 - \Delta k + 2 \cdot \delta k, \ldots, k_0, \ldots, k_0 + \Delta k.$$

The interval width is chosen to be (for virtually all the parameters k being investigated)

$$\Delta k = 50\% \cdot k_0,$$

and the grid step width is chosen to be

$$\delta k = 5\% \cdot k_0.$$

The following step (iii) is carried out for each of the grid values $k_{present}$.

(iii) Determine the optimum configuration $X_{k_{present}}$ matched to $k_{present}$ by minimizing the required function (= power generation costs) $f(x, k_{present})$ [with $k_{present}$ constant]. By substituting $x_{kpresent}$ or x_{k0} into the required function $f(., k_{present})$, calculate the values $f_{opt}(k_{present})$ or $f x_{k0}$ $(k_{present})$.
The sequence of the points $x_{kpresent}$ for all the grid steps with the k interval is a quantized version of the sought curve x_k of design optima [see aspect 1)].
Analogously, the sequence of the differences $f_{opt}(k_{present})$ - $f x_{k0}$ $(k_{present})$ represents a quantized version of the function "additional costs of choosing the standard configuration x_{k0}" (as a function of $k_{present}$) [see aspect 2)].

A practical example shows that 500 optimization calculations must be carried out to determine $x_{kpresent}$ in accordance with step (iii) for power station optimization with 25 cost parameters to be investigated, each of which has 20 grid steps. Bearing in mind that the computation time required per configuration optimization process is approximately one day, as a result of the numerous (several hundred) checks on the simulator 106 required for this purpose, it is less economic, for step (iii) to optimize each of

the design variables in the full real-value space. To overcome this, the search area is quantized, as is explained in the following text.

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Determination of the independent degrees of freedom

Results from optimization calculations such as high-line plots of the required function for selected section planes through this multidimensional variable space lead to the conclusion that the design optimum in

the variable space defined above are not isolated points but form a multidimensional subvariety. This is in turn an indication that the design variables are not in fact all independent of one another but are, in some cases, linked to one another by physical relationships. The number of degrees of freedom for the optimization may thus be reduced.

As explained above, the movement of design optima is intended to be calculated in the course of the sensitivity analysis. Isolated optima rather than entire optimum varieties are required for this purpose. Further section planes in the above variable space are defined deliberately in order to determine the actually independent degrees of freedom for the gas and steam design. The analysis of the high-line plots of the power generation costs on these section planes frequently leads to the global optimum of the power generation costs being located - approximately - in a **reduced search area** (that is to say in a subarea of the variable space mentioned above).

Concept of a simulation database

Every evaluation of the required function $f(x, k_{present})$ is carried out in two stages:

(1) An entire range of thermodynamic and geometric variables is calculated for each check with the simulator 106 as a function of the value x of the design variables, characterizing one configuration. These variables are then combined to form the vector s for the simulation data: s = s(x).

(2) The value of the required function (that is to say the power generation costs) is calculated from the simulation data s(x) as a function of the cost parameter constellation $k_{present}$.

The concept of a simulation database subdivides the required function calculation into two mutually independent programs.

Program 1 Starts a check with the simulator 106 in each case for any predetermined variable points x_i, and stores the simulation results $s(x_i)$ in the simulation database 202, which is preferably in the form of a file with a specific format. The cost parameters are irrelevant to this program.

Program 2 Calculates the value of the required function $f(x, k_{present})$ for a given cost parameter constellation $k_{present}$, for all the simulation data s stored in the simulation database 202 - and hence for all the variable values x on which this simulation data is based.

In combination with the grid concept, this results in the following procedure:

- The program 1 is used to apply grid points to the simulation database in advance.

- The required function values $f(x, k_{present})$ of all the grid points are calculated by means of the program 2 for each cost parameter constellation $k_{present}$ to be calculated. The grid point having the minimum required function value is noted as the optimum.

Significance of the cost parameters

The aim of the design optimization process is to minimize the power generation costs:

$$\text{Power generation costs} = \frac{\text{Investment costs} \times \text{Annuity}}{P_{\text{elec, gas and steam,net}} \times h_{\text{year}}} + \frac{b}{\eta_{\text{gas and steam}}}$$

The term "investment costs" is formed from the costs of the three individual aspects which are mainly affected by the design decisions,

- cold end,
- steam turbine,
- hot surfaces of the waste heat boiler and

- the costs of the remaining power station parts, which are referred to in summary form as "remainder of power station":

$$\text{Investment costs} = \text{Costs}_{\text{Cold end}} + \text{Costs}_{\text{Turbine}} + \text{Costs}_{\text{Hot surfaces of the waste heat boiler, gas and steam}} + \text{Costs}_{\text{Remainder of power station}}$$

Further reorganization of these individual investment cost terms result in those cost parameters becoming visible which influence these cost terms - in conjunction with the design variables:

(A) Cold end

$$\mathrm{Costs}_{\text{Cold end}} = \mathrm{Costs}_{\text{Cooling system: pipes/pumps}} + \mathrm{Costs}_{\text{condensor}} + \mathrm{Costs}_{\text{Cooling tower}}$$

$$\mathrm{Costs}_{\text{Cooling system: pipes/pumps}} = m_{\text{cooling water}} \times \mathbf{Price}_{\mathbf{kg/s,Cooling\ water}} + \text{Basic price}_{\text{Cooling system: pipes/pumps}}$$

$$\mathrm{Costs}_{\text{Condensor}} = \mathrm{Area}_{\text{Condensor}} \times \mathbf{Price}_{\mathbf{m^2,Condensor}} + \text{Basic price}_{\text{Condensor}}$$

$$\mathrm{Costs}_{\text{Cooling tower}} = \text{Basic area}_{\text{Cooling tower}} \times \mathbf{Price}_{\mathbf{m^2,Cooling\ tower}} + \text{Basic price}_{\text{Cooling tower}}$$

The costs of the cold end are thus critically influenced by the values of the following three cost parameters:

- specific costs of the cooling system ($\mathrm{Price}_{\text{kg/s,Cooling water}}$),
- price per square meter of condensor area ($\mathrm{Price}_{m^2\text{,Condensor}}$) and
- price per square meter of the cooling tower base area ($\mathrm{Price}_{m^2\text{,Cooling tower}}$).

(B) Steam turbine

A linearization process is carried out around a reference design point in order to model how the costs of the steam turbine depend on the HD temperature and the HD pressure:

$$\mathrm{Costs}_{\mathrm{Turbine}} = \mathbf{Costs}_{\mathbf{Turbine,reference}}$$
$$\times\ (1 + \mathrm{Correctionsummand}_{\mathrm{Turbine},\Delta p}$$
$$+ \mathrm{Correctionsummand}_{\mathrm{Turbine},\Delta T})$$

$$\text{Correctionsummand}_{\text{Turbine},\Delta T} = \mathbf{CorrTurb}_{\Delta T,\text{Gradient}} \times (T_{HD} = T_{HD,\text{Reference}})$$

$$\text{Correctionsummand}_{\text{Turbine},\Delta p} = \mathbf{CorrTurb}_{\Delta p,\text{Gradient}} \times (p_{HD} - p_{HD},\text{Reference})$$

The turbine costs thus depend on the following three cost parameters

- turbine costs for the reference design ($\text{Costs}_{\text{Turbine,Reference}}$),
- temperature dependency on the turbine costs ($\text{CorrTurb}_{\Delta T,\text{Gradient}}$),
- pressure dependency of the turbine costs ($\text{CorrTurb}_{\Delta p,\text{Gradient}}$).

(C) Heating surfaces

The costs for the individual boilers (which are physically identical) must be added up in order to obtain the costs for the total heating surfaces of a multishaft system:

$$\text{Costs}_{\text{Heating surface,gas and steam}} = \text{Costs}_{\text{Heating surface,Boiler}} \times \text{Number}_{\text{Boilers}}$$

The costs of an individual boiler are composed of:

- a lump sum, the cost parameter "lump sum for the heating surface costs per waste heat boiler ($\text{Costs}_{\text{Heating surface,fixed}}$)" and
- the contributions of the individual heating surfaces, which are dependent on the heating surface geometry, the materials used and the wall fittings, which depend on the boiler shape.

The costs of the individual heating surfaces are each influenced by the two cost parameters:

- basic price of the heating surfaces per square meter ($Price_{Heating\ surface,m^2}$) and
- price of the heating surface tubes per kilogram ($Price_{Heating\ surface,kg}$).

$$Costs_{Heating\ surface,Boiler} = Costs_{Heating\ surface,fixed} + \sum_{Heating\ surface\ i} Costs_{Heating\ surface\ i}(Price_{Heating\ surface,m2}, Price_{Heating\ surface,kg})$$

Both the basic square-meter price and the kilogram price are dependent on the materials.

(D) Remainder of the power station

The costs of the remainder of the power station can be modeled in two different ways:

(i) As proportional to the net total output of the power station;
Since the investment costs are divided by the net total output in the formula for the power generation costs, this approach results in only one constant which is the same for all design variants, that is to say the costs of the remainder of the power station are irrelevant to the optimization.

(ii) As an output-independent lump sum;
If this approach is chosen, the costs of the remainder of the power station are highly significant to the design optimization since, if the power station output is relatively large, the lump sum (converted to a per annum rate) is distributed over a relatively large number of kWh.

Certain parts of the remainder of the power station are modeled more appropriately by approach (i), and others by approach (ii), but the precise breakdown can be determined only with great difficulty:

$$\text{Costs}_{\text{Remainder of the power station}} = \text{Costs}_{\text{per kW}} \times P_{\text{elec, gas and steam, net}} + \textbf{Costs}_{\textbf{Remainder of the power station, constant}}$$

The three location-specific parameters:

- annuity,
- annual operating hours (h_{year}) and
- fuel costs per kWh combustion heat (b)

are investigated as the final group of cost parameters which, within the required function, govern the ratio between the investment cost and fuel cost proportion of the power generation costs.

Processor unit

Figure 5 shows a processor unit PRZE which is suitable for carrying out transformation and/or compression/decompression. The processor unit PRZE has a processor CPU, a memory MEM and an

input/output interface IOS, which is used in various ways via an interface IFC: an output can be displayed on a monitor MON and/or can be printed out on a printer PRT via a graphics interface. Inputs are made via a mouse MAS or a keyboard TAST. The processor unit PRZE also has a data bus BUS, which provides the connection from a memory MEM, the processor CPU and the input/output interface IOS. Additional components can also be connected to the data bus BUS, such as additional memory, data memory (hard disk) or a scanner.

List of references

[1] S. Schäffler: Global Optimization Using Stochastic Integration, Roderer-Verlag, Regensburg 1995.

[2] H. Ritter, T. Martinetz, K. Schulten: Neuronale Netze - Eine Einführung in die Theorie selbstorganisierender Netzwerke [Neural networks - An introduction to the theory of self-organizing networks], Addison-Wesley, 1990.

Patent Claims

1. A method for simulation of a technical system,
   (a) in which a required function depends on parameters and on predetermined setting constants;
   (b) in which a result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
   (c) in which the result is temporarily stored; and
   (d) in which the technical system is simulated on the basis of the result and of the setting constants.

2. The method as claimed in claim 1, in which the technical system is designed on the basis of the simulation.

3. The method as claimed in claim 2, in which the design process comprises adaptation of, a change to, or a redesign of the technical system.

4. The method as claimed in one of the preceding claims, in which the influence of the parameters on the technical system is redetermined by accessing the temporarily stored result.

5. The method as claimed in one of the preceding claims, in which the influence of each of a large number of sets of parameters on the technical system is determined by checking the external source, and the result of this check is temporarily stored.

6. The method as claimed in claim 5, in which an additional influence is determined on the basis of the temporarily stored results.

7. The method as claimed in claim 6, in which the additional influence is determined by interpolation or extrapolation.

8. The method as claimed in claim 6, in which the additional influence is determined from the results using an neural network.

9. The method as claimed in one of the preceding claims, in which the external source is a simulator or an experiment.

10. The method as claimed in one of the preceding claims, in which the simulation is carried out using a large number of results, without the external source.

11. The method as claimed in one of the preceding claims, in which the simulation of the technical system is used to determine the sensitivity of sets of parameters to changes in the setting constants.

12. An arrangement for simulation of a technical system, in which a processor unit is provided, which is set up such that:
(a) a required function depends on parameters and predetermined setting constants;
(b) a result in the form of an influence of the parameters on the technical system can be determined as a function of a predetermined set of parameters and on the basis of a request to an external source;
(c) the result can be temporarily stored; and
(d) the technical system can be simulated on the basis of the result and of the setting constants.

13. A computer program product for simulation of a technical system, which, when run on a processor unit, comprises the following steps:
(a) a required function depends on parameters and predetermined setting constants;

(b) a result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source;

(c) the result is temporarily stored; and

(d) the technical system is simulated on the basis of the result and of the setting constants.

Abstract

Method, arrangement and computer program product for simulation of a technical system

A method is specified for simulation of a technical system, in which a required function depends on parameters and predetermined setting constants. A result in the form of an influence of the parameters on the technical system is determined as a function of a predetermined set of parameters and on the basis of a request to an external source. The result is temporarily stored. The technical system is simulated on the basis of the result and of the setting constants.

FIG 1

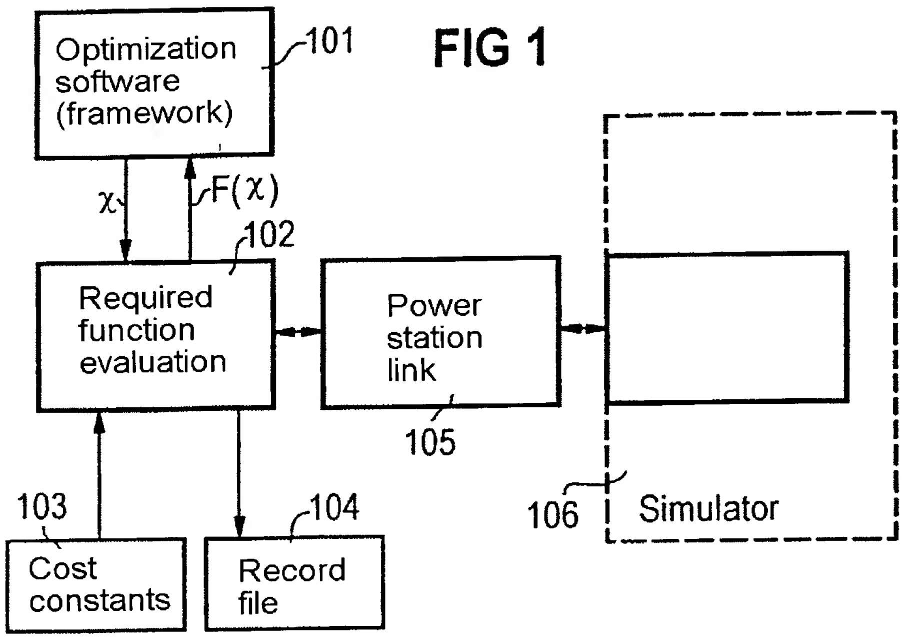
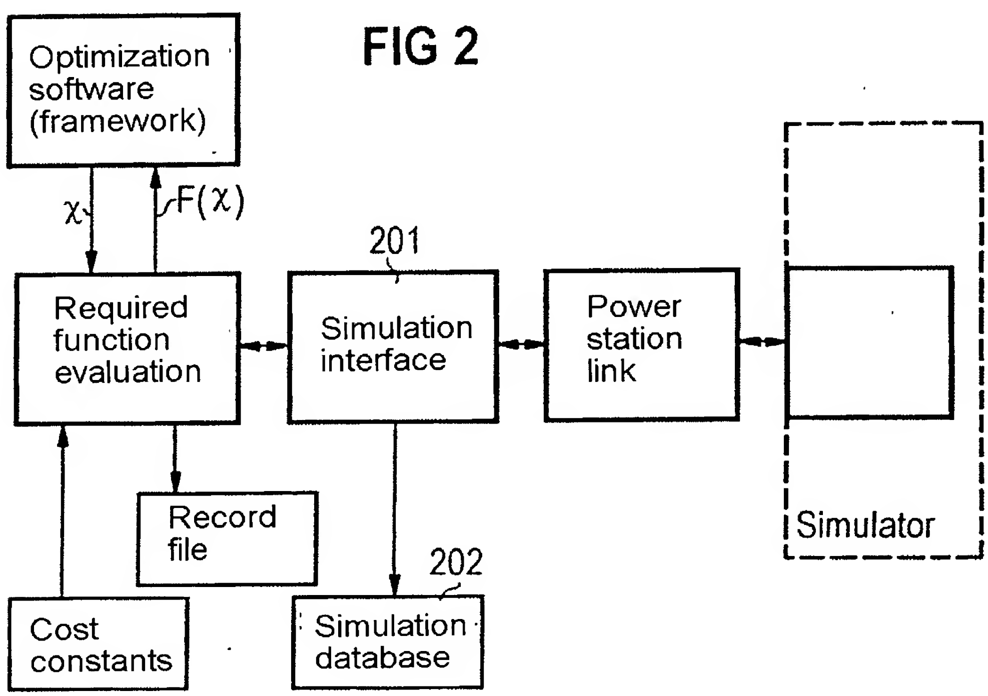

Optimization software (framework)
101
χ
F(χ)
102
Required function evaluation
Power station link
105
103
Cost constants
104
Record file
106
Simulator

FIG 2


Optimization software (framework)
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F(χ)
Required function evaluation
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Simulation interface
Power station link
Record file
Cost constants
202
Simulation database
Simulator

FIG 3

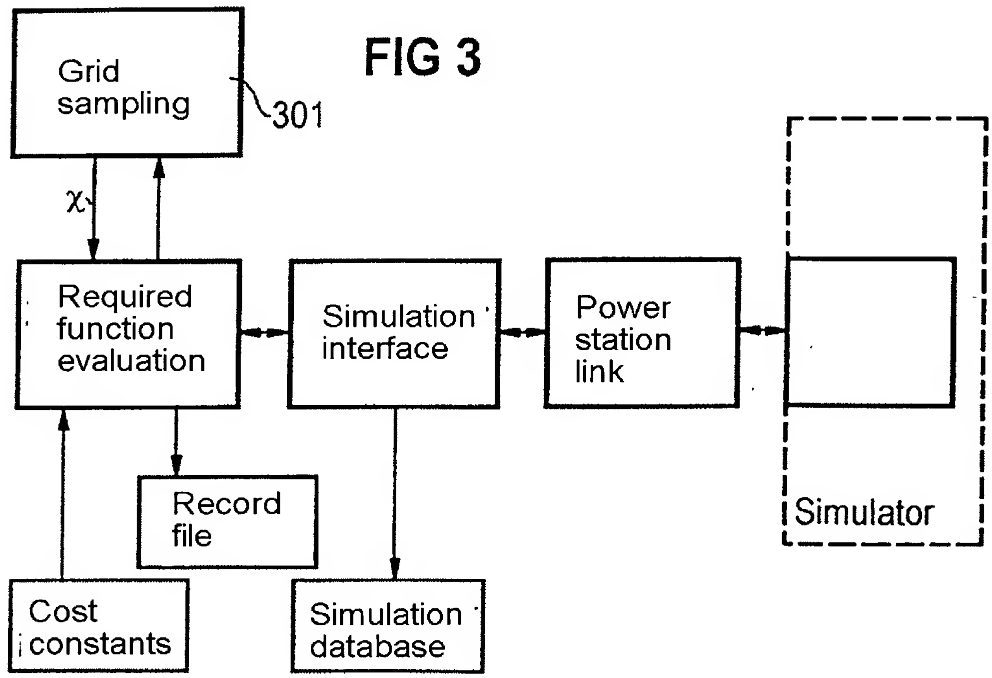

Grid
sampling
301
χ
Required
function
evaluation
Simulation
interface
Power
station
link
Simulator
Record
file
Cost
constants
Simulation
database

FIG 4

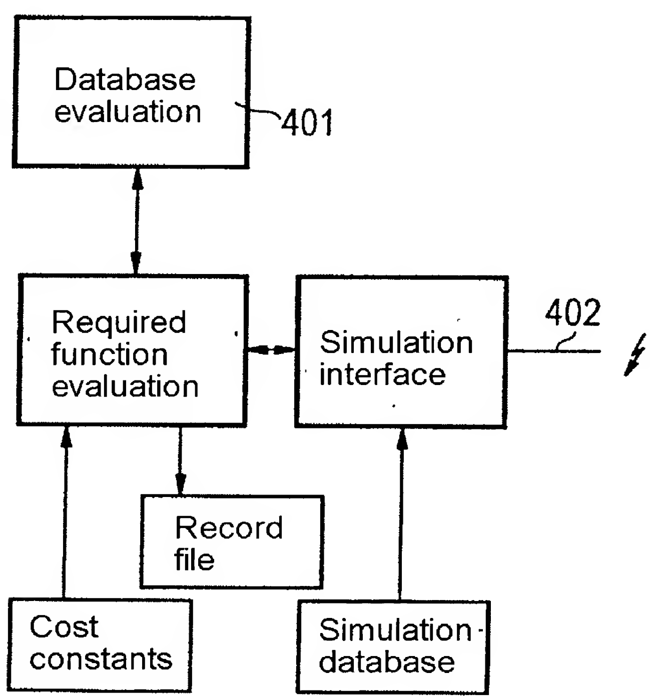
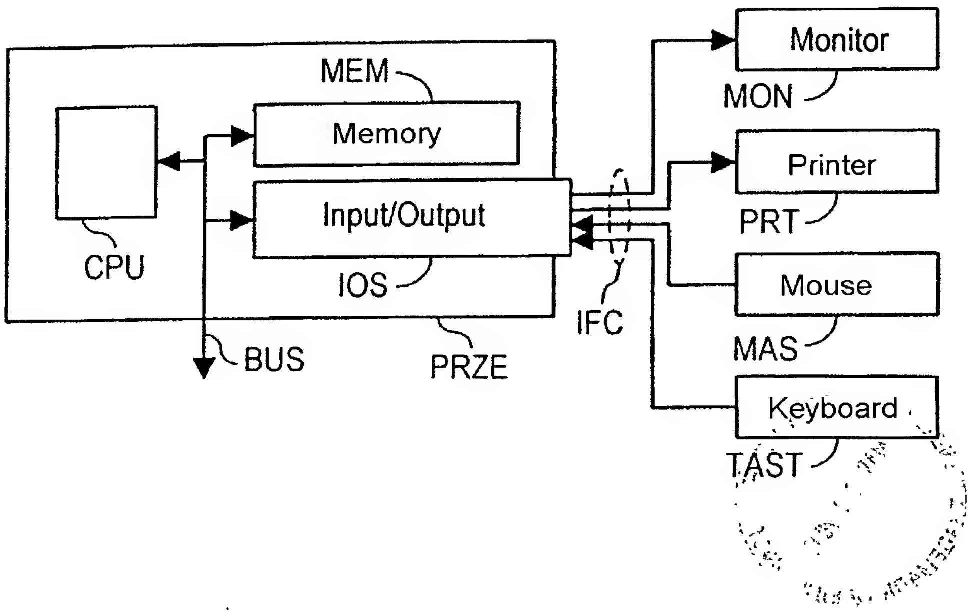

Database
evaluation
401
Required
function
evaluation
Simulation
interface
402
Record
file
Cost
constants
Simulation
database

FIG 5


MEM
Memory
Input/Output
IOS
CPU
BUS
PRZE
IFC
Monitor
MON
Printer
PRT
Mouse
MAS
Keyboard
TAST

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that.

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Verfahren, Anordnung und Computerprogramm-Erzeugnis zur Simulation eines technischen Systems

Method, arrangement and a product of a computer program for simulating a technical system

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 11.09.2000 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/DE00/03143
eingereicht wurde und am _______
abgeändert wurde (falls tatsächlich abgeändert).

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 11.09.2000 as
PCT international application
PCT Application No. PCT/DE00/03143
and was amended on _______
(if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign appplications
Priorität beansprucht

Priority Claimed

19945015.3 (Number) (Nummer)	DE (Country) (Land)	20.09.1999 (Day Month Year Filed) (Tag Monat Jahr eingereicht)	☒ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/03143 (Application Serial No.) (Anmeldeseriennummer)	11.09.2000 (Filing Date D, M, Y) (Anmeldedatum T, M, J)	anhängig (Status) (patentiert, anhangig, aufgegeben)	pending (Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

10085144 .032002

German Language Declaration

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

And I hereby appoint

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Direct Telephone Calls to: *(name and telephone number)*

Ext. ______

Postanschrift:

Send Correspondence to:

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Telephone: +1 703 390 3030 and Facsimile +1 703 390 3020
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Claus Hillermeier 2002/02/04

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Unterschrift des Erfinders / Datum: Claus Hillermeier 2002-02-04	Inventor's signature / Date: Claus Hillermeier 2002-02-04
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Staatsangehörigkeit: DE G.H. ~~2002-02-04~~	Citizenship: DE G.H. 2002-02-04
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Unterschrift des Erfinders / Datum: W. Märker 2002-01-28	Second Inventor's signature / Date
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Staatsangehorigkeit: DE	~~Citizenship~~: DE
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91330 EGGOLSHEIM	91330 EGGOLSHEIM

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(Supply similar information and signature for third and subsequent joint inventors).

10003044 .032002

3.00

Voller Name des dritten Miterfinders:	Full name of third joint inventor:
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~~Unterschrift des Erfinders~~ Datum 22.2.2002	~~Inventor's signature~~ Date 22.2 2002
Wohnsitz MUENCHEN, DEUTSCHLAND	Residence MUENCHEN, GERMANY
Staatsangehörigkeit DE	~~Citizenship~~ DE DEk
Postanschrift DAGLFINGER STRASSE 98	Post Office Address DAGLFINGER STRASSE 98
81929 MUENCHEN	81929 MUENCHEN

Voller Name des vierten Miterfinders:	Full name of fourth joint inventor:
Unterschrift des Erfinders Datum	Inventor's signature Date
Wohnsitz ,	Residence ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

Voller Name des fünften Miterfinders:	Full name of fifth joint inventor:
Unterschrift des Erfinders Datum	Inventor's signature Date
Wohnsitz ,	Residence ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

Voller Name des sechsten Miterfinders:	Full name of sixth joint inventor:
Unterschrift des Erfinders Datum	Inventor's signature Date
Wohnsitz ,	Residence ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

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(Supply similar information and signature for third and subsequent joint inventors).